ABOUT THE PROCESS OF DESIGNING RAILWAY INFRASTRUCTURE

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Abstract: Nowadays the process of designing railway infrastructure is mostly seen as a sequential process. The sequential approach would appear to be obsolete, since it is lacking a consideration of customer needs. Therefore, it must be widened and parts of processes must be considered as what they are: sub-processes in a bigger picture. Since the sub-processes are dependent on each other they can be depicted as a cycle. This article presents the cycle of designing railway infrastructure. It has its focus on the German speaking area and aims to give an overview to the tasks and the relationships between sub-processes. It concludes seven sub-processes and eight relationships. It starts with the customer needs for transport which have only been considered indirectly and are generally not one of the primary concerns for designing railway infrastructure. After that a political process determines how to correspond with these customer needs. It includes several inputs like funding, general laws for railway, and the geographic constraints. From the complex political process originates a design target, which is translated into an operational concept. These operational concepts differ in Europe with different focuses on the primary target and an example is discussed as a guide for further development. The operational concepts are then further processed with common evaluation tools to create the bases of design for the infrastructure. There are feedback loops from the evaluation tools to reconsider certain constraints from former sub-processes. After the evaluation tools conclude that an infrastructure is feasible, the infrastructure will be constructed. Later, a specific timetable is constructed on the basis of the infrastructure, which will then be used by customers to full-fill their needs.

Keywords: design, railway, infrastructure.

1. Introduction

The design of the railway infrastructure must take into account different requirements of technical, economical or environmental perspectives. In order to offer services on a railway infrastructure, the design of the track topology is essential. From the track topology, the other infrastructure can then be derived. The track topology therefore offers itself as the base for the design of railway infrastructure.
So far, the process of designing track topology was presented sequentially and processed accordingly (see figure 1, compare Walter, 2016, p. 56). At a closer look, however, shows that all the sub-processes (including first and last stage) are interrelated and therefore should not be considered separated from each other. It therefore makes sense to consider the design of track infrastructure and thus a track topology, as a continuous cyclic process. The cycle may extend over several decades. Since the design of the railway infrastructure is a strategic planning, the operational planning is not considered in the following description.

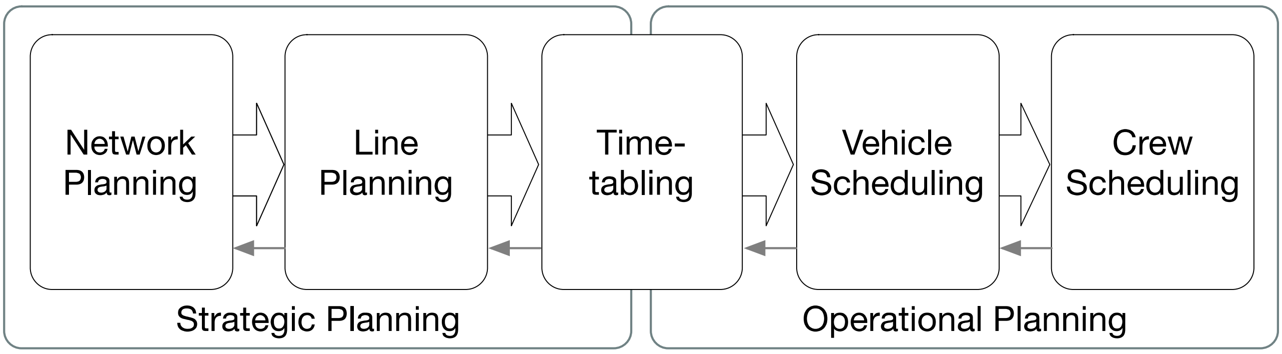

Fig. 1.
Sequential progression of infrastructure planning compare Walter (2016, p. 56)

2. Cycle of Track Topology Design

The individual sub-processes of the cycle can run parallel to each other. Figure 2 illustrates a perception of this cycle. Following paragraphs will discuss the different stages (marked with a circle, i.e. Ⓐ) and their transitions (marked with a diamond, i.e. <0>) in the cycle.

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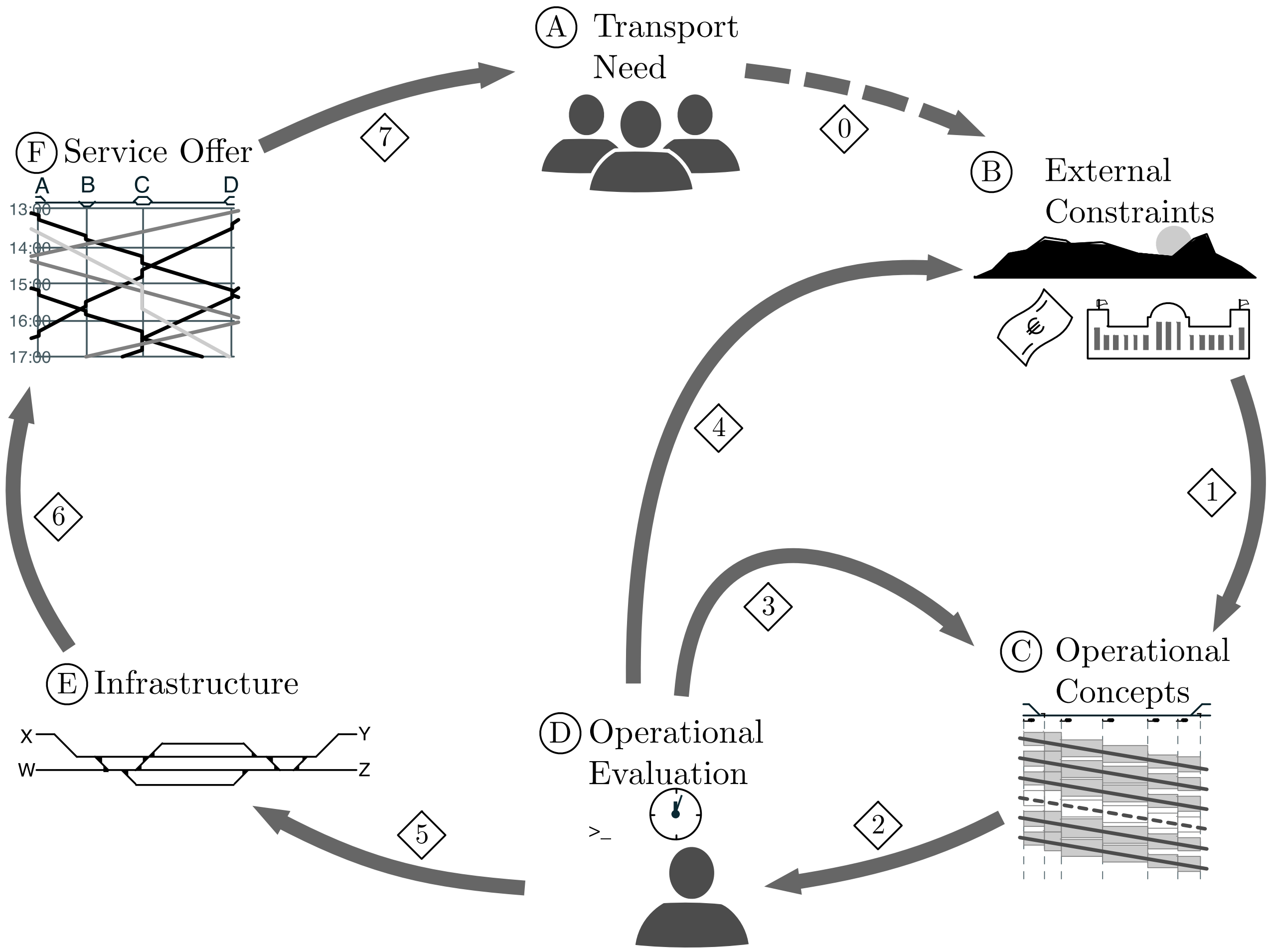

Fig. 2.
Cyclic progression of track topology design

Ⓐ
Means of transport are built for people. People use means of transport to ship goods or travel as a passenger. Use of transport is triggered by the user needs.
The needs come from the spatially relevant basic functions of existence: home, work, care, education and recreation (compare Partzsch, 1970). To satisfy the needs, passenger traffic arises as a mediator between the locations of the individual basic functions of existence. Freight traffic arises from the spatial structure of the economic fabric which provide goods or services to consumers. Needs cannot be satisfied arbitrarily and are in feedback with the transport offer. Therefore, in general, the *transport needs* of users are bundled in corridors and balance against the impact of traffic for the public interest. With this balancing the transport need can be limited in time and space. Spatially through the provision of service and in time by peak, off-peak periods and night's rest.
<0>
A transport demand is derived from the transport need. The derivation is formed by modelling the transport needs in dividing the basic functions of existence in areas which is called a traffic model. There are different models with different gradations to detail and input variables. For instance a traffic model is the Model EVA described in Lohse and Schnabel (1997, p. 250 ff.).
The input parameters and the result of a model need interpretation and training in the handling. Since the interpretation cannot be completely objective, it needs scientific and political work to derive instructions. The instructions from science and politics must not be mutually consistent.
Often the instructions are characterized by the historically developed problem solving strategy in a specific geographic region. Those instructions will be based on the external constraints.
Ⓑ
Under *external constraints* are geography (topology, demography, economic structure, etc.), financing and legal/political directives summarised. All external constraints can be influenced.
The geographical constraints can be influenced by means of engineering works (such as tunnels or bridges), but this is only possible if they are funded. Politics can be influenced by the political will of a region, which in turn affects the legal and financial constraints. Nowadays the political will is mainly influenced by concerns of the financing.
Financing takes place primarily by the public sector in the form of transfer payments. Schwarz (2003) describes how the funding of infrastructure is organised on several levels within a framework of financing arrangements in Germany.

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Part of the framework is subsidising transport services as offers on the infrastructure. Offers are created by transport service agencies and are awarded through tendering processes.
Non-financial policy guidelines are implemented through regulation, legislation and related institutions. Riesen (2007) describes how far and how successful regulation are carried out to implement social and economic policy objectives. Motherby (2009) shows how extensive legal regulations can be. All government activities are accountable to laws that are drafted and shaped by the legislative. Institutions such as the German "Bundesnetzagentur" subsequently enforce politically motivated regulation of the transport market within their means.

<1>

From this complex political process specifications arise that are brought to the infrastructure managers. However, at least in Germany, the state infrastructure policy has a major contradiction between restructuring of the state-owned company (i.e. DB AG) and handling a federal-state conflict in infrastructure financing (compare Riesen, 2007, p. 134 ff.). This conflict leads to partly inconsistent or contradictory specifications.
A sensible way to address this is the possibility to define a *service intention* for lines and networks (compare Mahadevan, 2007). Service intention describes holding pattern, operating intervals and times for network sections. E.g. an integral periodic timetable can be adapted by additional trains for higher traffic demand during peak hours. The infrastructure can then be put into dimension based upon such a service intention. In most cases the specifications are not as detailed as a service intention. Usually the specifications are based on desired development stages, which are subsequently determined as a target network.

Ⓒ

The specifications may vary depending on the railway line and location in the network. Often the requirements for capability and behaviour for a railway line are in accordance with the UIC Code 406 (see UIC, 2004). Nevertheless, the sole consideration of capability and behaviour is neglecting the aspects of user-oriented services. Therefore, requirements of service and *operational concepts* are combined.
Operational concepts may vary according to speed, stopping patterns, type of train as well as by primary and secondary networks (compare Weigand and Heppe, 2013, p. 444 ff.). A possible operational concept for a railway line could consist of a superimposed periodic traffic with different holding patterns for passengers and additional freight trains for example. In contrast to a service intention an operational concept is more detailed concerning the data for vehicles and infrastructure.
The larger the area considered, the more complex the operational concept. This way the complexity of a concept of operations for a single region is different than for an entire country. To reduce the amount of data to what is necessary, the area and the level of detail is adjusted. In Radtke (2014, p. 56 ff.) distinction is made in three levels of detail:

- Macroscopic,
- Mesoscopic,
- Microscopic.

By the combination of the considered area, operational concept and level of detail, the inputs are formed (<2>). These inputs are used in the form of a timetable and a desired infrastructure in a railway operation research analysis.

Ⓓ

Operational evaluations are performed to make predictions on the feasibility of a specific concept. For that various tools are available (see Pachl, 2002, p. 137 ff.).
To utilize these tools in a reasonable way, an educated guess is required. The educated guess is an assumption based on knowledge and experience and therefore likely to be correct. However, it results in a lack of transparency of the process and the results. The complex and extensive data storage and many variable factors of each tool make it mandatory that an user contributes experience and knowledge in the handling. Furthermore, the tools have a little intuitive user interface (UI) and use UI concepts from the late nineties.
When performing an operational evaluation with the tools, the creative process of planning is often in the background, data management and data purity are usually more essential. Only a good data pool makes the operational evaluation feasible. In addition, a complex operational evaluation requires high personnel and time effort (compare Martin and Schmidt, 2010). To make the operational evaluation more comprehensible, it requires simple and understandable ways to explain all decisions and document them. Due to the number of variables alone that possibility is severely limited. In total, a better transparency of procedures and results would be desirable.
The result of the operational evaluation is a prediction/estimate about the performance of a concept. If the evaluation meets the original specifications of Ⓑ, the basis for the track topology (<5>) is created. If the evaluation does not meet the specifications, either the specifications or the concept must be adapted.

<3>

Changing in the input variables from the operational concept within the specifications of Ⓒ occurs frequently. The cause of the change is the iterative nature of the operational evaluation (compare Weigand and Heppe, 2013, p. 490). The input variables are altered to approximate a target value in the iterations. The target value is based on existing variables. The educated guess is most commonly used so that the alteration is as close as possible to the goal.
The change is generally a slight modification of the timetable. Otherwise, it may be conducted by infrastructure-side changes (e.g. signal or switch locations or altered track numbers and connections).

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<4>
It could be that it is not possible to change the input variables of the operational concept within the specifications. Then the project must either be discontinued or the specifications are to be adapted to make it possible. The adaption then has to be done within the margins of external constraints Ⓑ. One obvious way is to change the mode of financing. Nevertheless, there is also an option to examine the legal framework of operation and therein make other arrangements effective (e.g. BOStrab[2] instead of EBO[3]).
Some operation research analyses are used to evaluate feasibility and recommendations as to the public sector. An example is the feasibility study about the "Deutschlandtakt" (see BMVI - Bundesrepubik Deutschland, 2015).
Ⓔ
When the operational research analysis is completed, specifications (<5>) are formed and the *infrastructure* is constructed by building, adapting or overhauling. The new construction or the adaptation of infrastructure is carried out by a project promoter and the construction firm. However, the ideal condition of the infrastructure after the implementation is only of limited duration. Over its lifetime, the railway infrastructure comes to wear and measures might be taking to ensure traffic safety. This is also a possibility for change in traffic demand. Therefore, a continuous adjustment of the offer (<6>) is necessary.
Ⓕ
In preparation of the *service offer* methods of timetable construction are used (compare Pachl, 2002, p. 175 ff.). The input variables are obtained from the infrastructure, for that an institution (i.e. transport association) or a transport company is able to create an offer. Different timetables are generated depending on the traffic volume in the operational concept Ⓒ. Some timetables are created beyond the scope of the operating concept. Those are e.g. seasonal timetables with additional offers or timetables in phases of maintenance or renewal work.
Due to the timetables a range of transportation links are fabricated. Those links are utilized by users to satisfy their needs of transport (<7>).

3. Conclusion and Critique

The sequential consideration of the design of railway infrastructure appears outdated. It is therefore necessary to extend and represent the dependencies of the sub-processes in a cycle. The transport needs of the user is considered only indirectly and is not commonly in the foreground. The specifications for the design come from complex political processes, which are transferred into service and operational concepts. These concepts are reviewed and assessed to turn them into a basis for the infrastructure and consequently into a timetable.
The cyclic progression of track topology design shows how its individual sub-processes interact. The consideration of the cycle, facilitates the structuring of methods for targeted design of track topology. Since the means of transport are generally established for users, the question arises whether the process should be oriented closer to the traffic demand Ⓐ of the users.
Users can generally only react to the timetable Ⓕ. Without knowing the transport needs, one can make any assumptions for the timetable in the operational concept Ⓒ without consequences. Only after the restructuring of F a timetable it may become evident that the users had other transport needs. There is an urgent need for a stronger focus on traffic demand modeling (<0>).
At the same time, there is a lack of discussion about how far to give in to traffic demand. Even if and where a limit on the fulfillment of the transport need exists. The question of how to find the balance between resource use and free development of mobility needs arises.
The discussion is mainly a social one and primarily driven through politics. Riesen (2007) shows, however, that this task is carried out only to a minor extent. Also missing are binding target definitions within the framework of service intentions (<1>).
In order to implement the service intention purposeful, the design process must move into the foreground with the tools of operational evaluation Ⓓ. Currently, these tools are not comprehensible without an educated guess, and are therefore centered on the feasibility. It is important to make the know-how communicable and comprehensible on a larger scale.

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[2] The "Verordnung über den Bau und Betrieb der Straßenbahnen" ("Ordinance on the Construction and Operation of Street Railways" / light railway regulations), is a German law regulation governing the field of tramway, metro and light rail operations.
[3] The "Eisenbahn-Bau- und Betriebsordnung" ("Ordinance on the Construction and Operation of Railway" / railway regulations), is a German law regulation specifying rules and regulations for railways.

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